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The use of weather forecasts in building automation and control systems (BACS): How to use them? What is the benefit?

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Presentation on June 13th 2007
in the Workshop 9 “Enhanced use of weather data and forecasts to improve the energy efficiency and indoor environment in buildings”

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Siemens Switzerland Ltd, Building Technologies Group, Zug, Switzerland

The use of weather forecasts in building automation and control systems (BACS): How to use them? What is the benefit?

Content:

- Is there a benefit of using weather forecasts in BACS?
- What kind of weather forecasts can be used in BACS?
- What should the BACS do with the weather forecast?
- How big is the benefit?
- Some remarks
- A new cooperative research project: OptiControl
- Some questions and requests to you

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Is there a benefit of using weather forecasts in BACS?

Yes, sometimes there is a benefit.

And sometimes it is very obvious.
Some examples:

Is there a benefit of using weather forecasts in BACS?

1. Example:
Atrium of the
office building Grafenau
in Zug, Switzerland

The control of the sun-blinds and of the vents by the BA-system.

The **goal** of the control is to generate in the atrium a **moderate climate.**
This reduces heating and cooling loads in the neighboring offices.

The control strategy to achieve this goal is:

- **If** it is a hot summer day **then** Control mode **REJECT** (The BA-system controls the blinds and vents such that the temperature in the atrium is as low as possible).
- **If** it is a cold winter day **then** Control mode **COLLECT (**The BA-system controls the blinds and vents such that the temperature in the atrium is as high as possible).
- **If** it is a mid-season day **then** ????????

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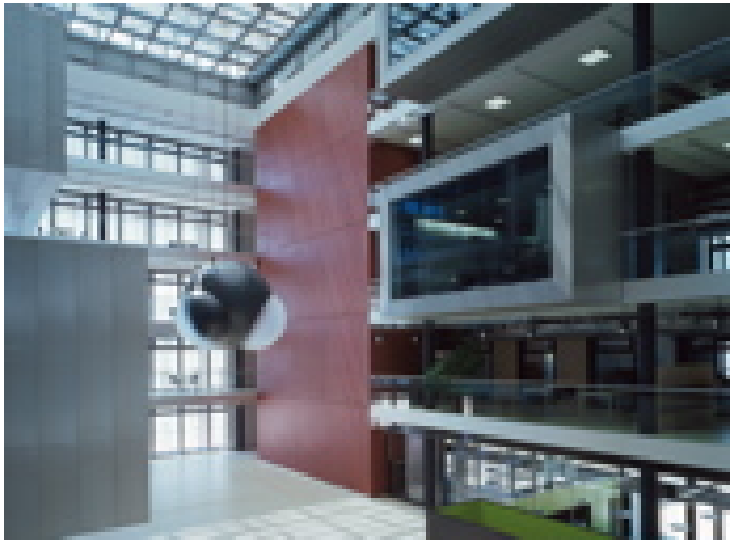
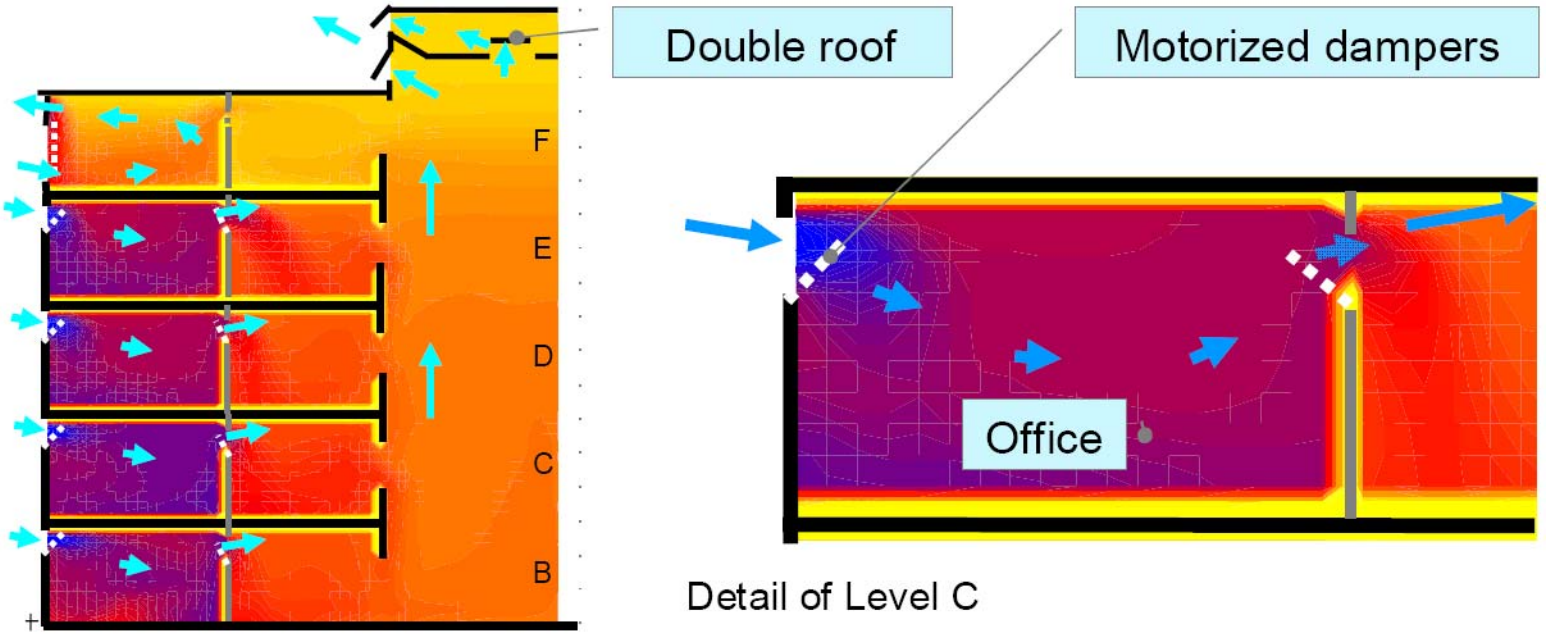
•**If** it is a mid-season day **then** The BA-system should have a weather forecast...

Is there a benefit of using weather forecasts in BACS?

2. Example:
New Building of
EAWAG (ETH Domain),
Switzerland



Cooling of the office rooms by natural ventilation during night.



Detail of Level C

We expect from a control strategy:

- **If** it is a hot summer day **then** the BA-system controls the lamellae so that no direct sun light enters the building and it switches on the natural ventilation during night.
- **If** it is a cold winter day **then** the BA-system controls the lamellae so that the sun light enters the building and it does not switch on the natural ventilation during night
- **If** it is a mid-season day **then** ??????????????

We expect from a control strategy:

- **If** it is a hot summer day **then** the BA-system controls the lamellae so that no direct sun light enters the building and it switches on the natural ventilation during night.
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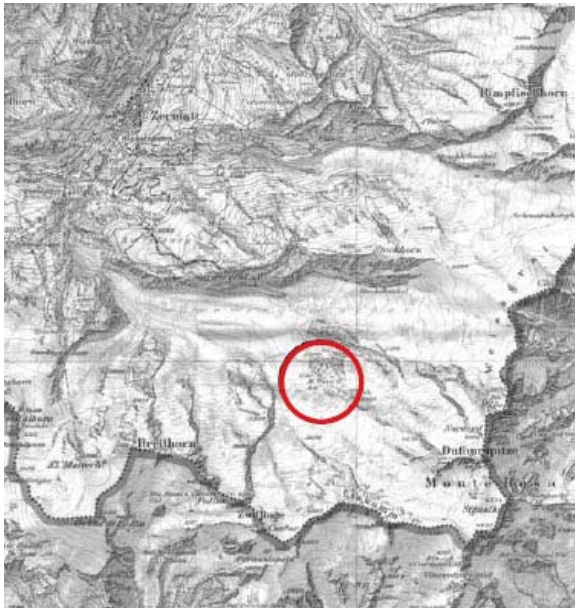
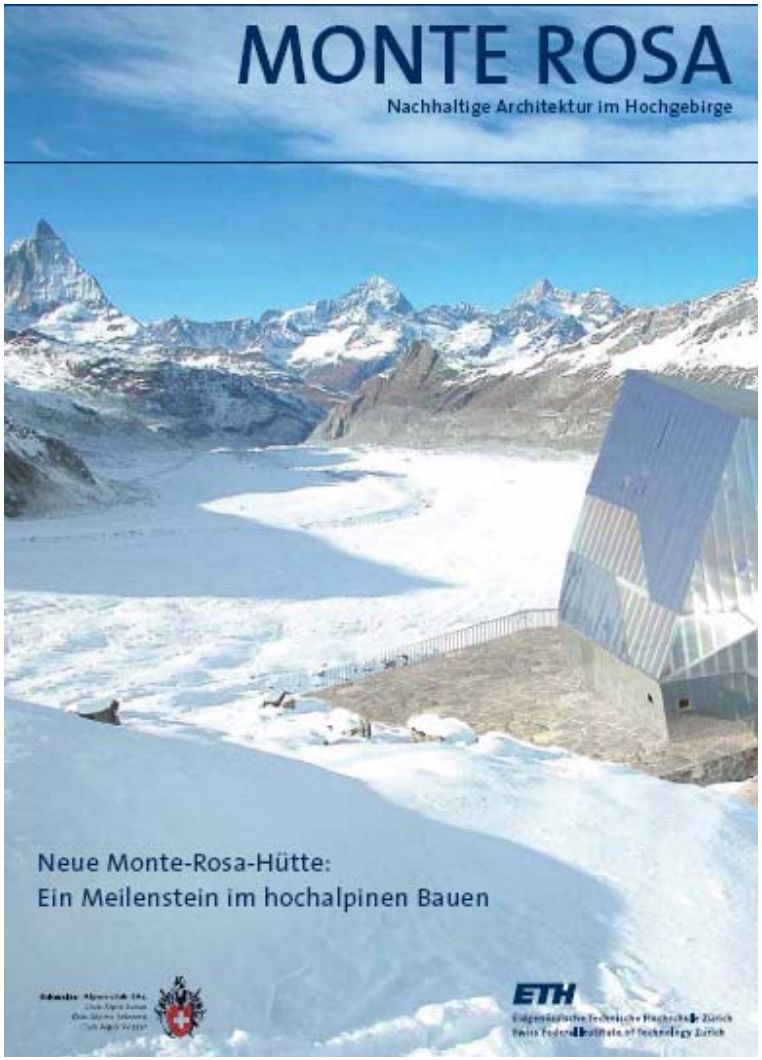
- **If** it is a mid-season day **then** The BA-system should have a weather forecast

Is there a benefit of using weather forecasts in BACS?

3. Example:
New Monte Rosa cabin.
A project of the ETH
to its 150th anniversary.

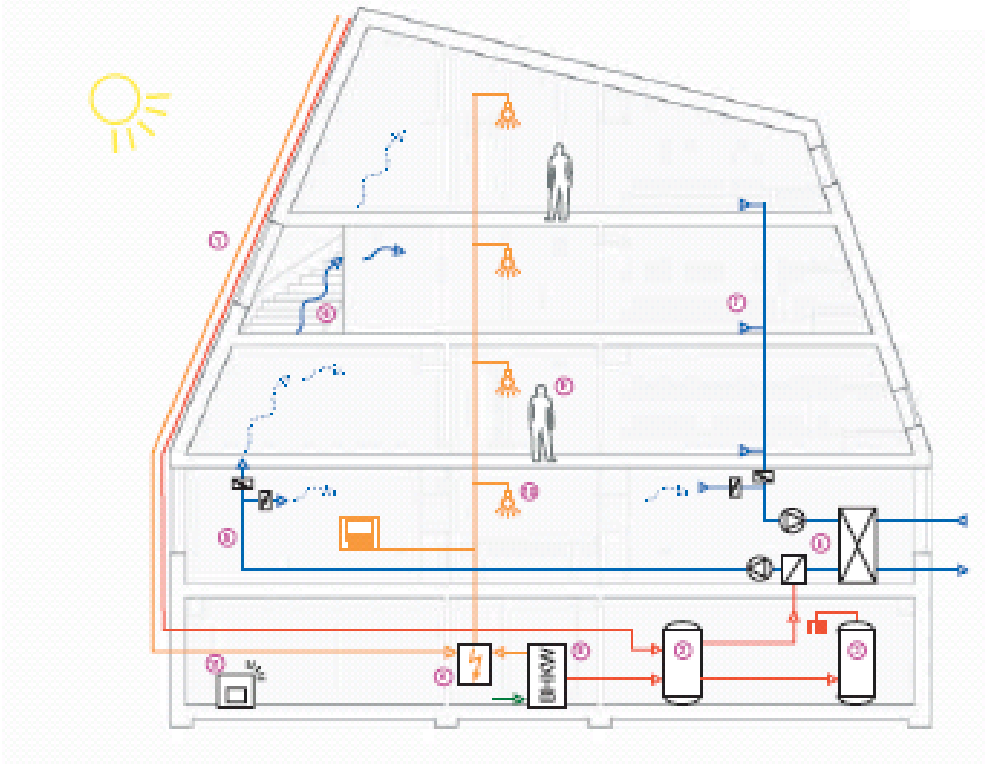




The energy and HVAC system.

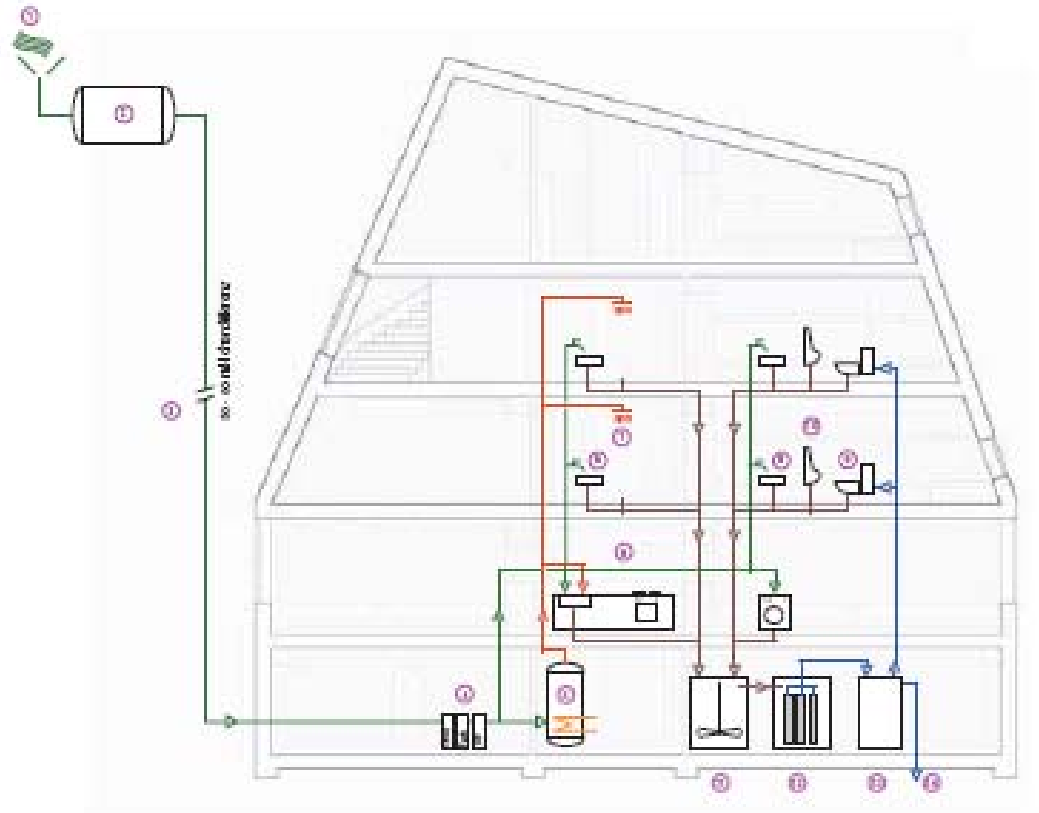
Luft
Thermische Energie
Elektrische Energie
Brenngas

1. Solarfassade
   Thermische Kollektoren
   Photovoltaik-Zellen
2. Thermischer Speicher
3. Warmwasserspeicher
4. Elektrospeicher/Verteilung
5. Lüftungsgerät
   Lufterhitzer
   Wärmerückgewinnung
6. Zuluft via Treppenhaus
7. Abluft im Zimmer
8. Blockheizkraftwerk
9. Personen als interne Wärmequellen
11. Elektrische Geräte
12. Holzofen im Winterraum



Schema der Energieversorgung

The water system.

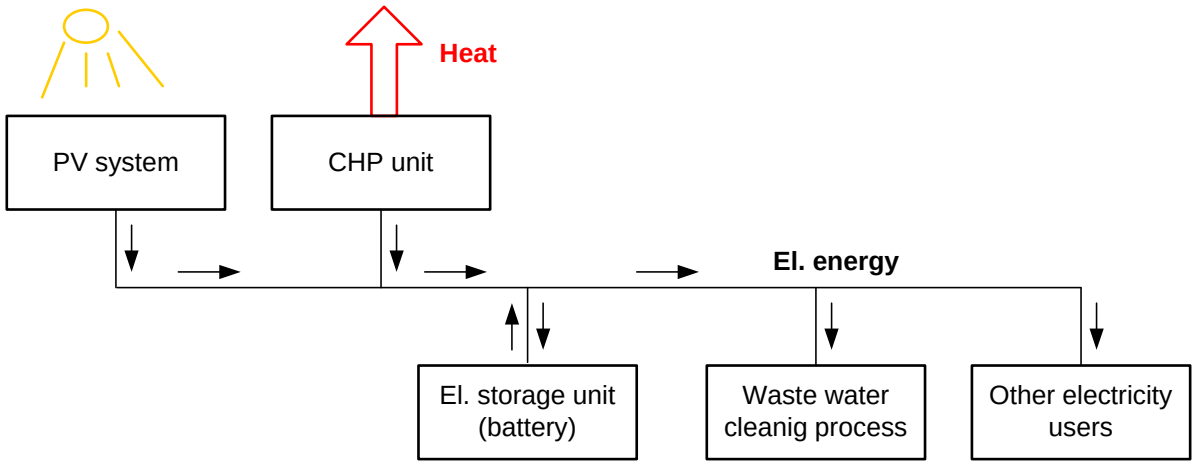


Brauchwasser kalt
Brauchwasser warm
Abwasser
aufbereitetes Wasser

1. Schmelzwasserfassung, Quelle
2. Reservoir
3. Druckleitung
4. Filtrierung Brauchwasser
5. Wassererwärmer
6. Küche
7. Duschen
8. Waschtisch
9. Toiletten
10. Urinoir (wasserlos)
11. Abwasser Sammelbehälter
12. Mikrobiologie / Membrankläranlage
13. Geklärtes Abwasser
    Rückführen zur WC-Spülung
14. Ablassen in die Umgebung

Schema des Wasserkreislaufs

The control of the waste water cleaning process by the automatic controller.



When should the controller switch on the waste water cleaning process?

We expect from a control strategy:

- **If** the battery is half full **and** the waste water tank is half full **and** a lot of sun is expected for the near future

  then the controller switches on the cleaning process,

  to reduce the risk, that solar energy will have to be rejected because the battery will be fully loaded.

- **If** the battery is half full **and** the waste water tank is half full **and** no sun is expected for the near future

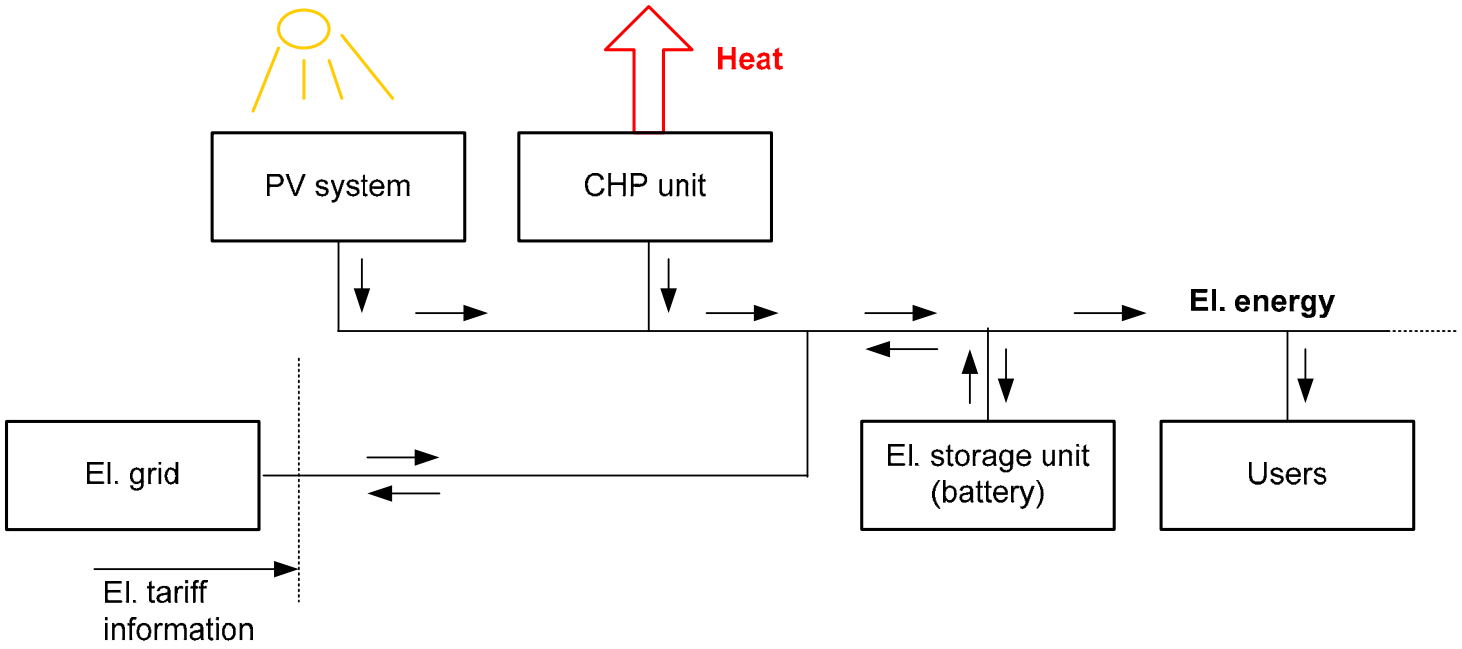
  then the controller switches off the cleaning process,

  to reduce the risk, that battery will get empty and therefore the COP-unit has to be switched on to supply the other electricity consumers with energy.

Is there a benefit of using weather forecasts in BACS?

4. Example:

A building with PV panels, CHP-unit, etc.
connected to the public electricity supply net and
with variable or even dynamic electricity prices.



The use of weather forecasts in building automation and control systems (BACS): How to use them? What is the benefit?

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What kind of weather forecasts can be used in BACS?

Some possibilities:

- Weather forecasts from a weather service institution
- Weather forecasts generated by the controller itself
  e.g. using “tomorrow as today”-predictions or by extrapolation of the past.
- Weather forecasts from a weather service institution, inclusive uncertainty measures of the predictions
  Examples for uncertainty measures of predictions:
  - Variance (in the probabilistic sense)
  - Variation interval (bounds)
  - Ensemble predictions with probabilities
    (Probabilistic forecasts with COSMO-LEPS, LEPS = Local Ensemble Prediction System)

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What should the BACS do with the weather forecasts?

Some possibilities:

- Rule based approach, i.e. applying rules of the form „**If** …….. **then** …….**“**
- Replace measurements by forecasts
- Model predictive control (MPC)
- Stochastic approaches

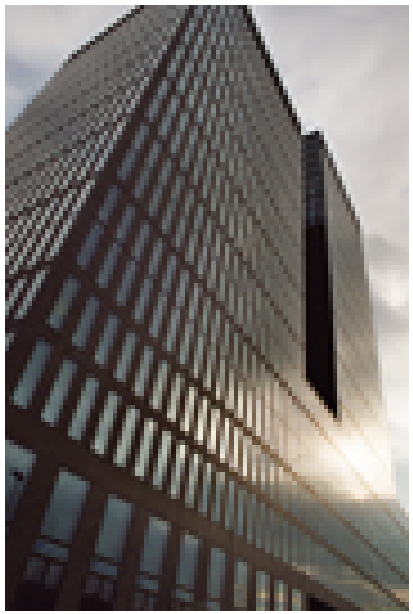
What should the BACS do with the weather forecasts?

Replace measurements by forecasts:

Controller for TABS using weather forecasts form MeteoSwiss:

Leonardo office building in Zurich

Sunrise Tower in Zurich



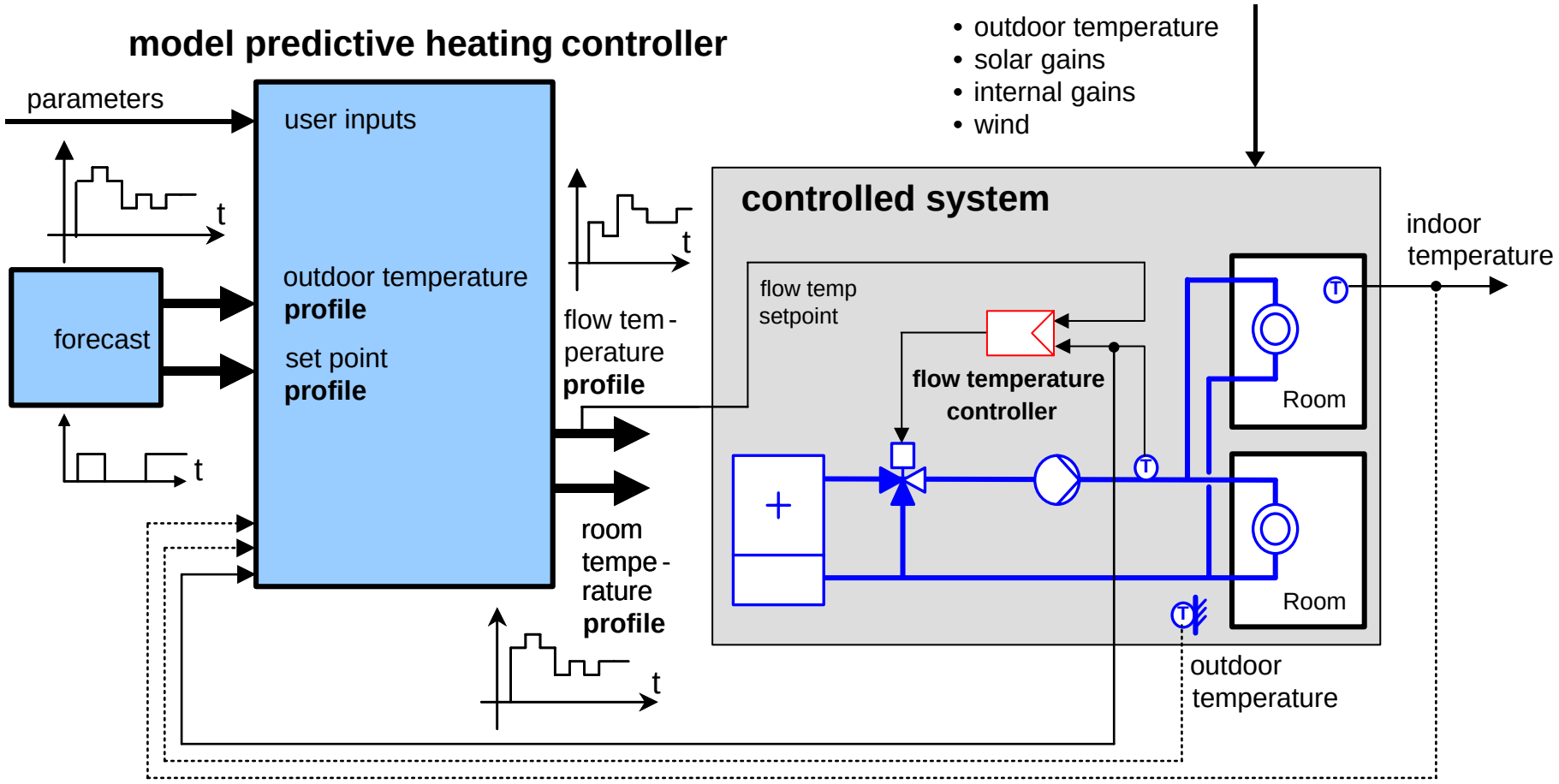
What should the BACS do with the weather forecasts?

Model predictive control:

An example: a model predictive heating controller

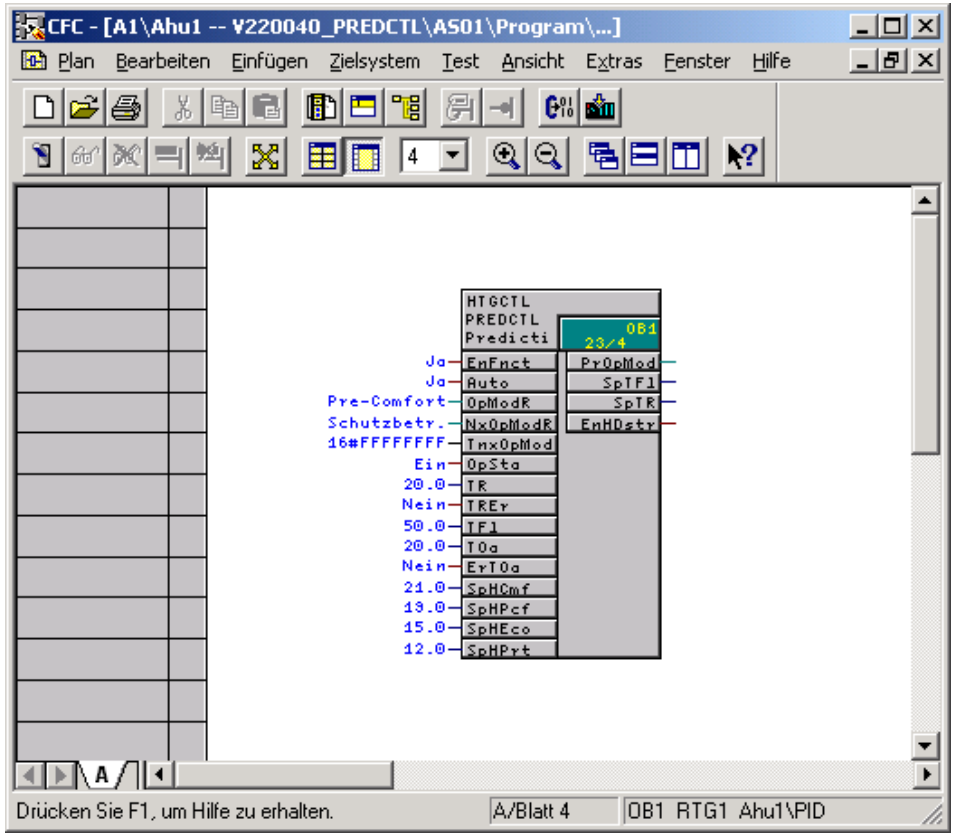
Published in:

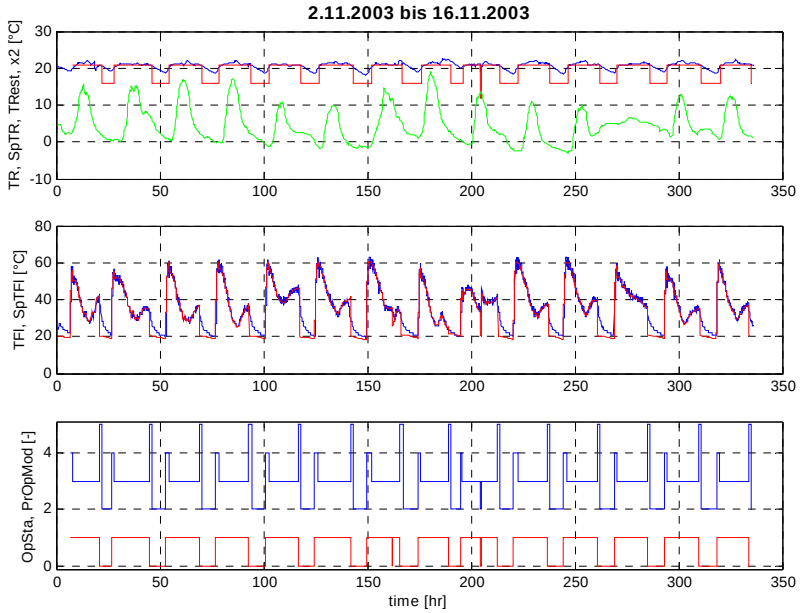
“Predictive Control for Heating Applications”,
P. Gruber, M. Gwerder, J. Tödtli,
CLIMA 2000, Napoli, 2001.


model predictive heating controller
parameters
user inputs
t
forecast
outdoor temperature
profile
set point
profile
t
t
flow tem -
perature
profile
room
tempe -
rature
profile
t
• outdoor temperature
• solar gains
• internal gains
• wind
controlled system
flow temp
setpoint
flow temperature
controller
Room
Room
indoor
temperature
outdoor
temperature

Implementation of predictive heating control **in DESIGO PX, α-testing**

- test site residential building Garmisch (G. Lehnerer)
- test site office building Vienna (RC Austria)





Model predictive heating controller

Customer benefit:

- With this controller we have a fully adaptive heating controller.
  (Two versions of model predictive heating controllers have been developed:
  1. a version which is manually tuned; 2. an adaptive version, which is automatically tuned)

- Fast reaction on room-temperature set-point steps:
  Current solutions are only fast for the change from the operation mode ECO to the operation mode COMFORT.

- Automatic exception handling,
  as for example the reduction or prevention of night and weekend set-back in cold days if a heat generator is not oversized.

Model predictive heating controller

Additional benefit:

- It is our first model-predictive heating controller in an automation station of a BACS:
  - Proof of feasibility.
  - Identification of the HW requirements for other MPC which are more computation intensive
- We have an alternative to the Neurobat controller.

What should the BACS do with the weather forecasts?

Stochastic approaches:

They take uncertainty in the weather and in the forecasts explicitly into account, by using probabilistic models.

Two important types of stochastic control approaches
- Open loop feedback optimal (also called: Closed open loop control)
- Optimal closed loop control

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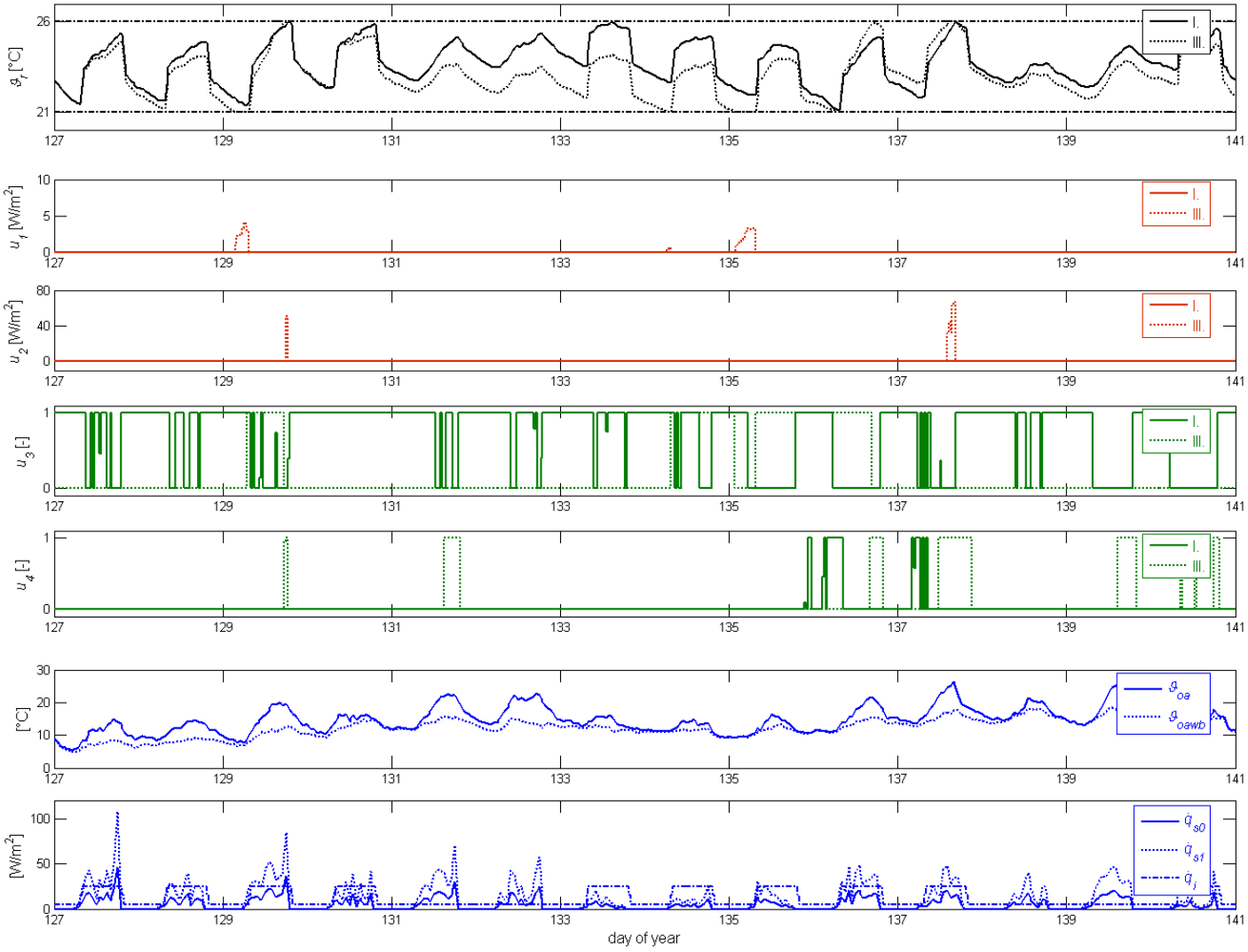
How big is the benefit from using weather forecasts in BACS?

Many publications appeared to this question in the last 25 years.

Let us look to just one:

“Predictive Control for Integrated Room Automation”,
M. Gwerder, J. Tödtli,
CLIMA 2005, Lausanne, 2005.

Predictive control for integrated room automation: simulation results I



Control strategy I:

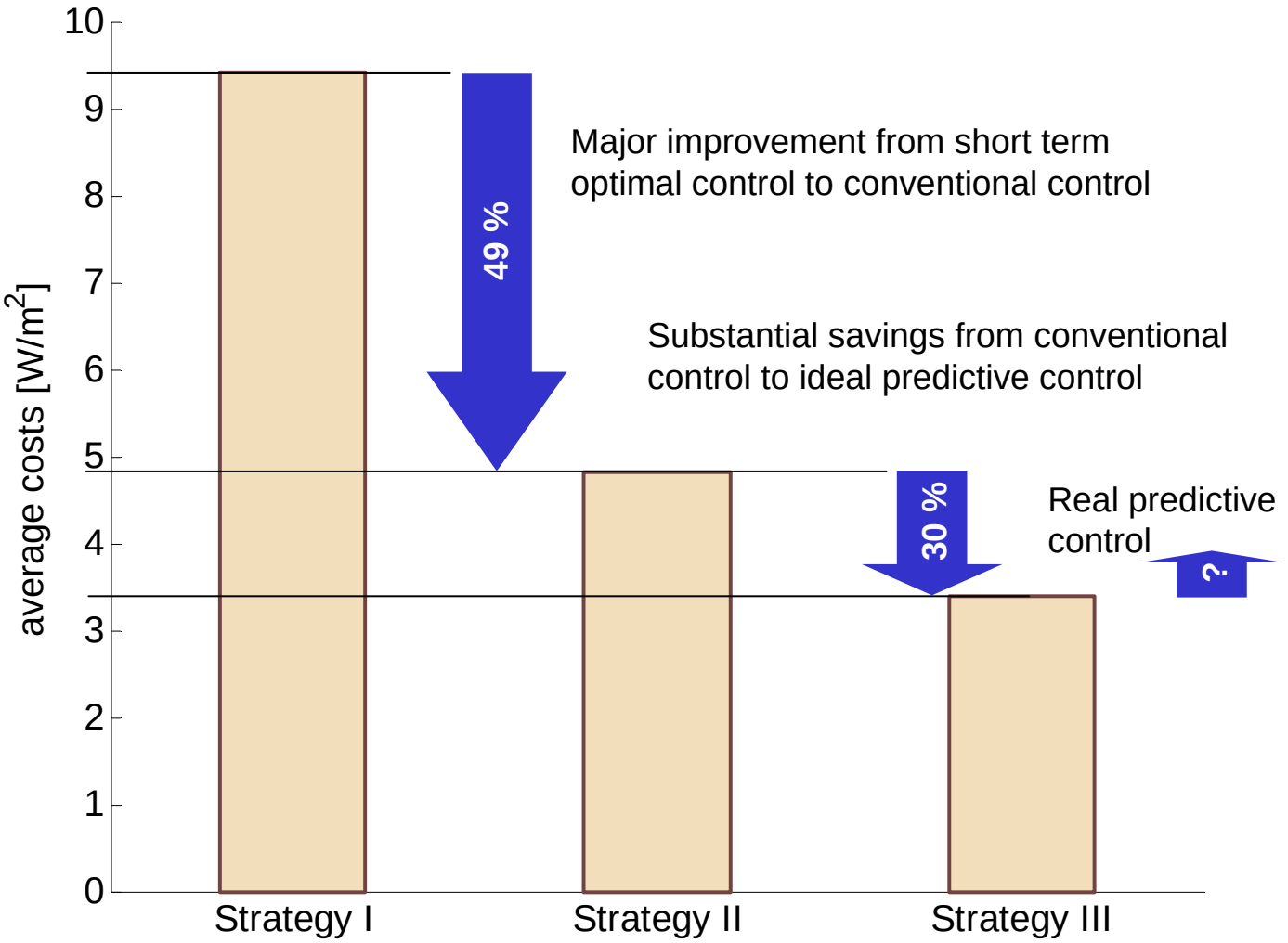
Ideal predictive control (performance bound)

Control strategy II:

Short term optimal control

Control strategy III:
conventional control example

Predictive control for integrated room automation: simulation results II



Control strategy I:

Short term optimal control

Control strategy II:
conventional control example

Control strategy III:

Ideal predictive control (performance bound)

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Some remarks:

- **Two kinds of predictive control applications:**
  - Applications where a wrong prediction leads to a violation of comfort requirements
  - Other applications

  Uncertainty measures of the predictions will generally be more useful in the first kind of applications.

- **Predictive control is plausible for a lot of people**
  - We hope that it is therefore more widely used
  - And that it is easier to sell it!

Some remarks (cont.):

- **Two kinds of implementation of model predictive control:**
  - In a controller
  - In a remote server connected via web to the BACS

- **The time is now mature for model predictive HVAC controllers using weather forecasts!**
  - Cheap powerful processors are available
  - Powerful communication networks are available
  - Good weather forecasts are available

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A new cooperative research project: OptiControl

Use of Weather and Occupancy Forecasts for Optimal Building Climate Control (OptiControl)

Project partners:

- ETH Zurich, Terrestrial Systems Ecology (Project leed)
- ETH Zurich, Automatic Control Laboratory
- EMPA Building Technologies (ETH domain)
- MeteoSwiss, Federal Office of Meteorology & Climatology M
- Siemens Building Technologies

Duration: 2007 until 2010

Funded by:

- Swisselectric Research
- CCEM (ETH domain)
- Siemens Building Technologies

What we – Siemens – expect from the project OptiControl:

- One or more predictive control algorithms
- To each algorithm:
  - What kind of weather and/or occupancy forecast is used
  - The algorithm its self
  - A method to engineer, to commission and to tune the algorithm
  - A method to monitor the performance of the controlled system during operation (as far as possible)
  - A user guide if necessary (the most important elements of it)
  - A cost/benefit analysis, which shows the promising applications for different types of buildings, different types of use and different climates.
    Or a tool to determine it with reasonable effort.
- For control algorithms with a good cost/benefit ratio:
  - A first prototype controller
  - First results from Alfa Tests

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Some questions and requests to you

•Do you know interesting **publications** on the use of weather forecasts or of predictive control in BACS?

•Do you know about **real applications**?

•Do you know about **standardization proposals** for the communication of weather forecasts to TABS?

Please **send answers to** the project leader of OptiControl, Dimitros Gyalistras at ETH, E-mail: gyalistras@env.ethz.ch

References to such publications or real applications will be published on the website of the project OptiControl:

http://www.sysecol.ethz.ch/OptiControl

or

http://ccem-ch.web.psi.ch and navigate to OptiControl.

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Thank you for your attention